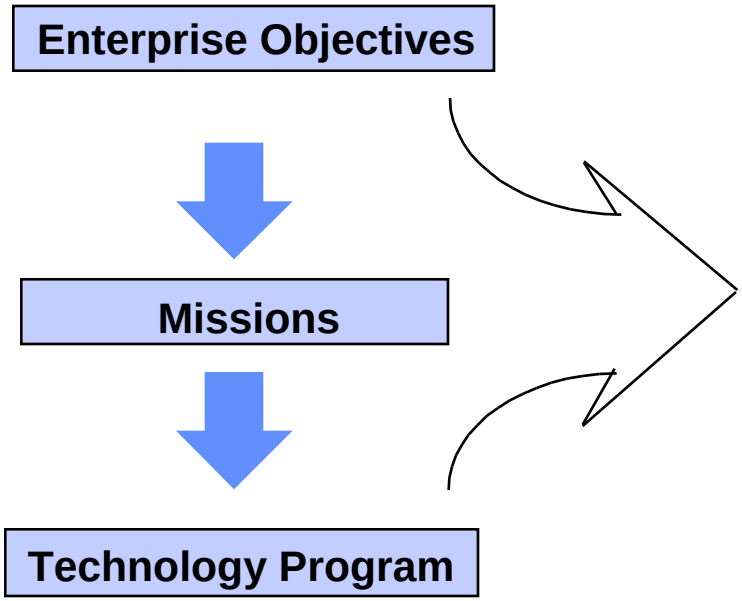
Earth Science Enterprise
--
Technology Development and Infusion

YF/Granville Paules

March 2000

Agenda

- **New Direction, Goal, and Objectives**
- **Functional Organization, Relationships, Guidelines**
- **Strategic Planning Products**
- **Technology Program Implementation/Accomplishments**
- **Program Oversight/Performance Metrics**
- **Next Steps**
- **Challenges and Opportunities**



Enterprise Objectives

Technology Program

Missions

Enterprise objectives established

Missions sets derived from Enterprise objectives

Technology programs derived From mission requirements

Enterprise objectives drive technology

Technology expands mission horizons

Missions evolve from convergence of objectives and technology

Technology Program Objectives

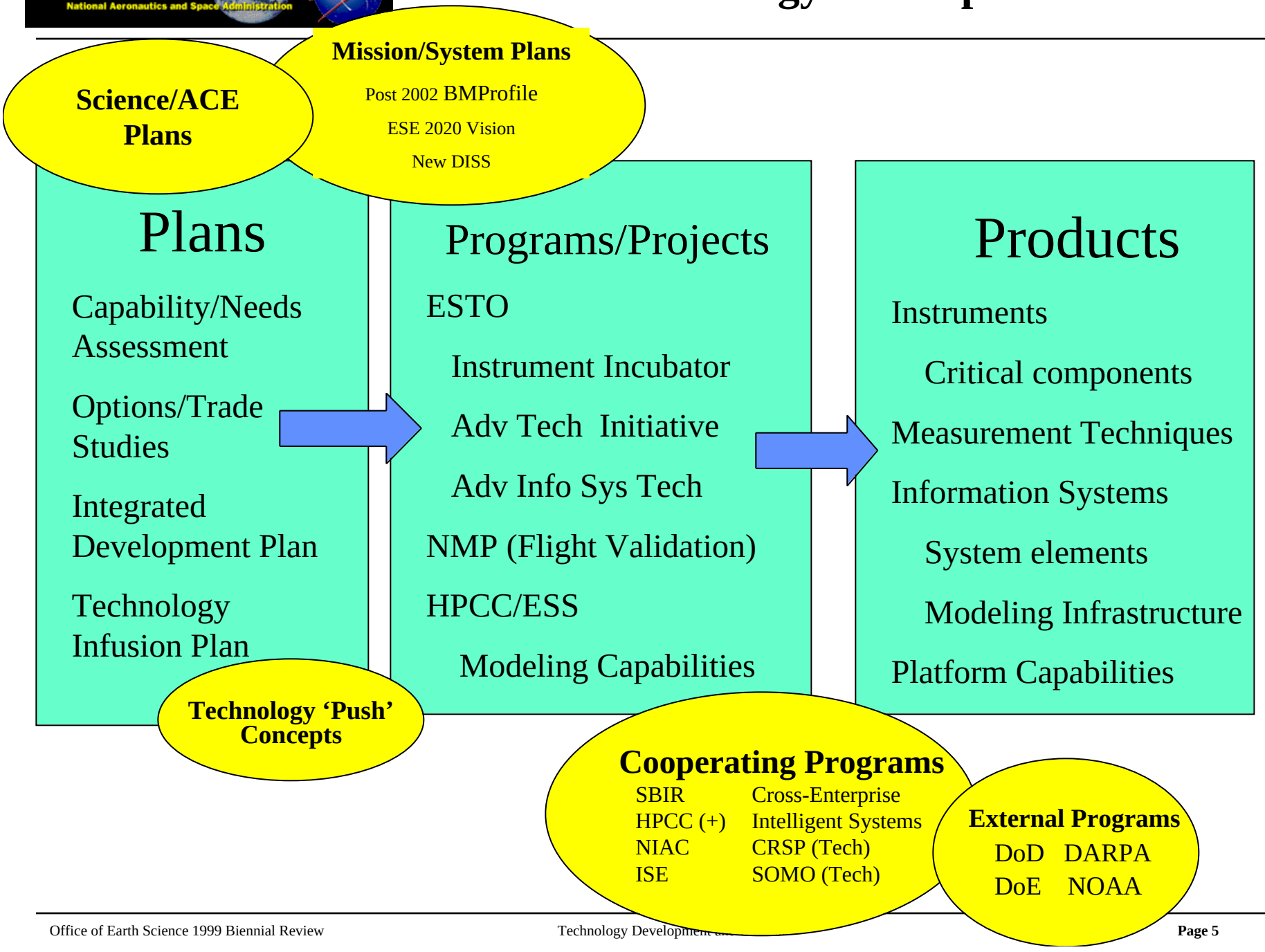
Goal

- Develop and adopt advanced technologies to enable mission success and serve national priorities

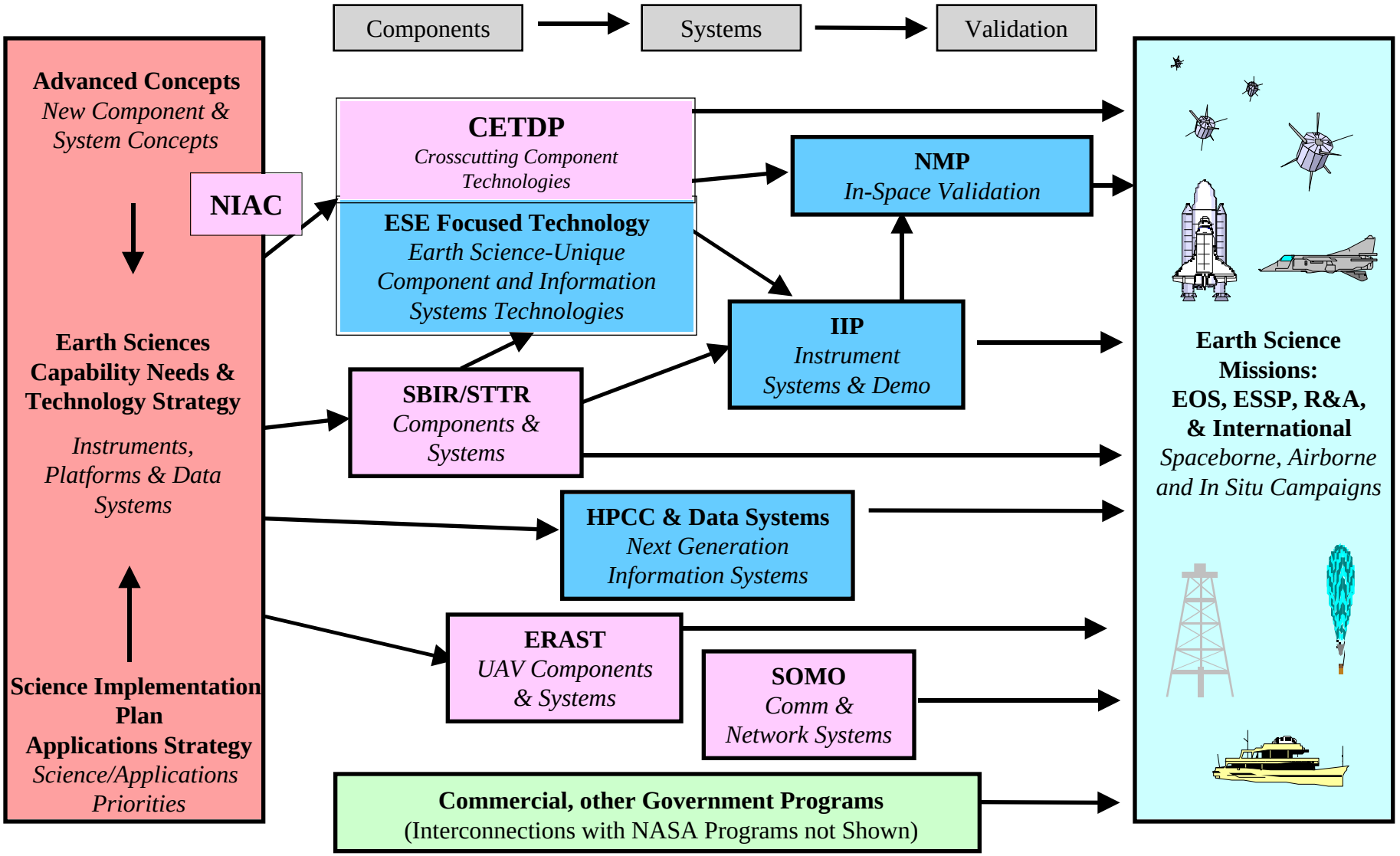
Objectives

- Develop advanced technologies to reduce the cost and expand the capability for scientific Earth observation
- Develop advanced information systems for processing, archiving, accessing and visualizing, and communicating Earth science data
- Partner with other agencies to develop and implement better methods for using remotely sensed observations in Earth system monitoring & prediction

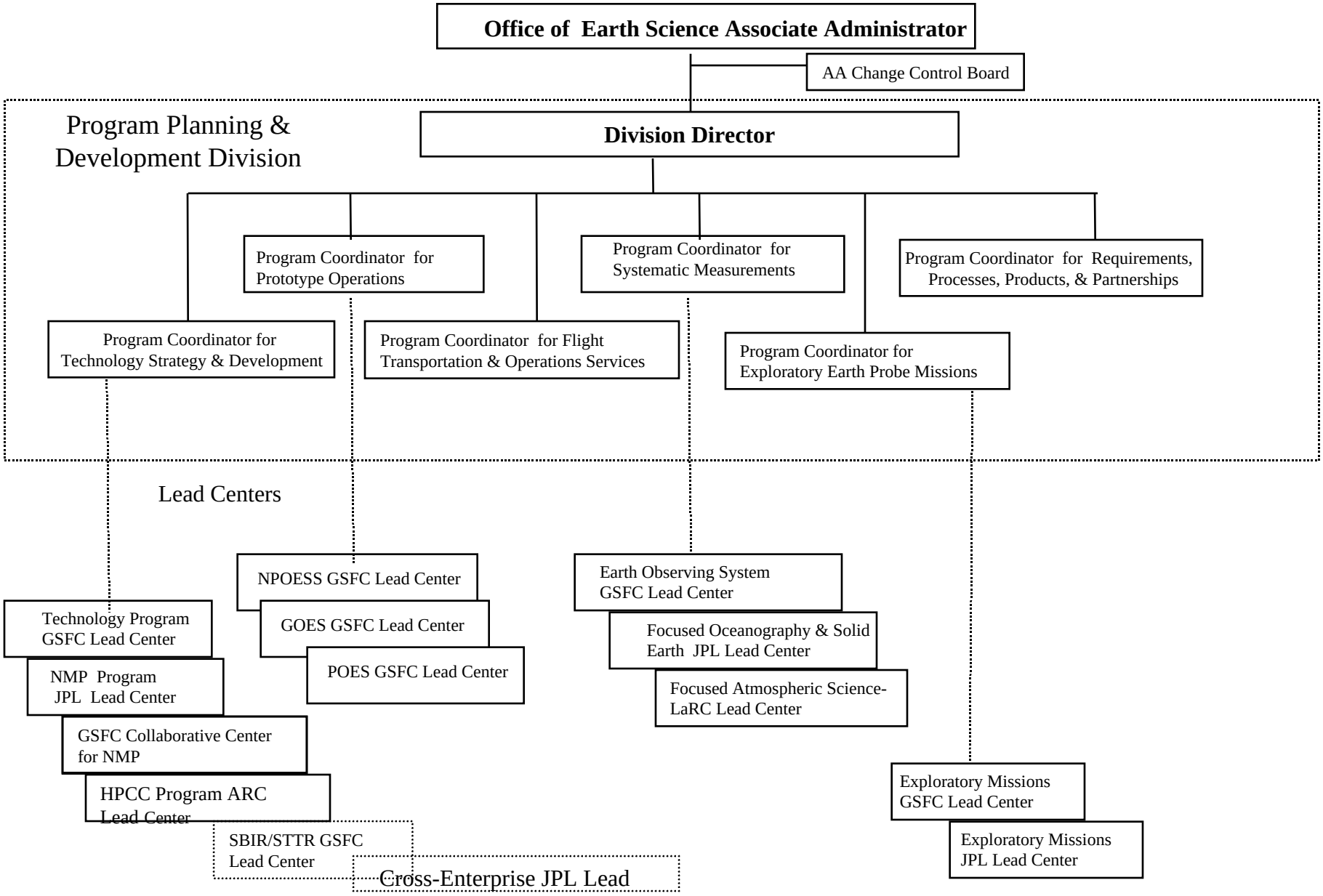
ESE Technology Development



Technology Development Program Elements



PP&D Program Management Structure



Management Guidelines

- Unified set of Driving Requirements
- Enterprise goal of 10% of Annual Budget for Technology Development
- Three Time Horizons for Technology Delivery (annual funding)
  - **Near (50%)- Now through Early Post 2002 Mission Support**
  - **Mid (25%)- Later Post 2002-2010 Measurement Scenarios**
  - **Far (25%)- Vision era Measurement/Observation Scenarios**
- Acquisition Policies
  - **Competitive/Directed/Partnerships**
- Linked/Hierarchical Performance Metrics
  - **Effectiveness of meeting driving requirements/objectives**
  - **Efficiency of delivery**
- Full incorporation of Cross-enterprise investments
  - **SBIR/Codes 632/IS/ISE/HPCC/et al**

Strategic Planning Products

Strategic Planning Products

Technology Strategy

- **APPROVAL--** by AA OES in June 1999

Technology Program PCAs

- **APPROVAL--** by A/AA OES in September 1999

Capability/Needs Assessment

- For use in FY 2000 investment planning
- Science/Applications Workshop Inputs--Fall 1999
- **CONCURRENCE--**YS/YO/YF DDs--February 2000

Integrated Technology Development/Investment Plan

- FY 1999 Completed and in use at ESTO
- FY 2000/01/02 In development--draft Jan 2000, final April
  - Includes FY00-05 budget planning horizons
  - Will summarize all Technology Programs-ESTO/NMP/HPCC
  - Supports FY 2002 POP Guideline preparation
- **CONCURRENCE--**YB/YF DDs

Annual Technology Infusion Plan

- Underlying basis--Science Implementation Plan/Applications Strategy
  - identifies LRD/ORD need dates
  - reflects projected technology availability dates based on roadmaps
  - consistent with budget commitment
- **CONCURRENCE--**YS/YO/YF DDs

Requirements Development

- **Science Research Plan**
- **Applications, Commercialization, and Education Strategy**
- **Baseline Measurement Profile Studies**
- **Long-term Enterprise Vision**

Post 2002 Baseline Measurement Process

- **Easton, MD Workshop--Summer 1998**
  - Measurement Concepts identified and prioritized
  - Academy Review--October 1998
- **Baseline Measurement Studies --Spring/Summer 1999**
  - Measurement Concepts translated to candidate mission concepts and options
  - Candidate nominal mission profiles studied in reasonable detail
  - Critical technologies initially identified
- **Technology Needs Assessment--Summer 1999**
  - Aerospace Corp performs independent review
  - Synthesis of technology needs completed for BMPS candidate concepts
  - Results incorporated in Technology Capability/Needs Assessment
- **Concept incorporation in Science Research Plan--Now Underway**
- **Measurement Concepts selected for Formulation--January 2000**

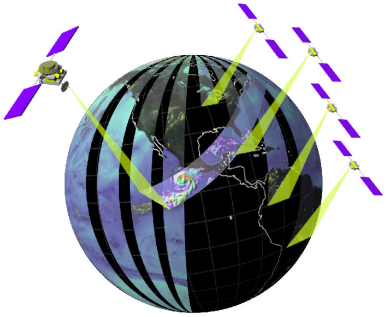
Integrated Technology Plan To Enable Global Precipitation Measurements

Objective:

- Provide systematic estimation of global precipitation with three hours or less sampling interval
  - •Improved weather forecasting
  - •Global water cycle understanding

Technology Challenges:

- Integrated Observatory with autonomous constellation control and operations
- Optimized inter-satellite communications for data handling and downlink
- Large aperture deployable structure
- Large aperture radiometers
- Autonomous space/ground internet protocol



Instrument Incubator Program


Imager

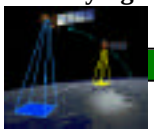

Dual-Freq. Radar Elec.


Drone Radiometers

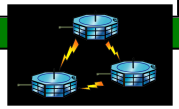
Global Precipitation Observation Strategy

Baseline LEO Science | **Enhanced LEO Science/GEO**

Formation Flying



Autonomous Constellation Control/Operations



Deployable Structure

Launch

Launch

NMP Validation Flights

EO1 Launch (April'00)

ST5 Launch (Sept'03)

Launch (Mid'05)

Other Technology Development Programs


Lithium Ion Battery

Rad Hard Pentium Processor


Autonomous Internet Protocol


Dual-freq Deployable Radar Antenna


Constellation/Microsats

FY 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10

Nominal Time Frame

Earth Science Long Term Vision

A society with the ability to gather and understand Earth Science information and make proactive, timely environmental predictions and decisions at all relevant geographical and societal levels.

Needs Supporting the Long Term Vision

- **Need observational capability that provides**
  - Continuous viewing of key phenomena on a global scale
  - Ability to autonomously detect an event or critical condition

- **Need computational models that can provide high quality, real-time, regionally- and locally specific forecasts**
  - Requires understanding of processes that allow for interpretation of observation and inclusion in models

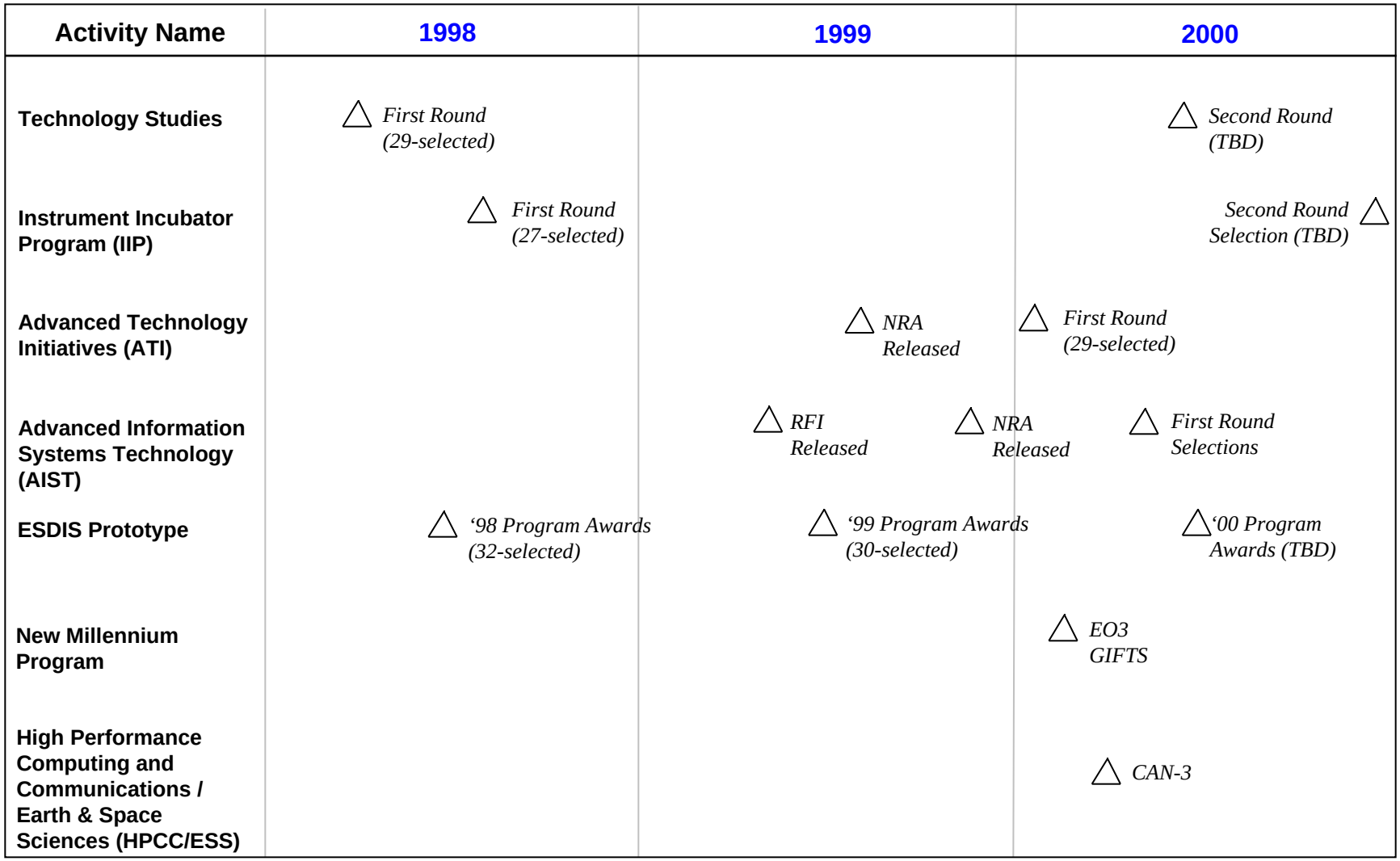
- **Need data delivery system that can get critical information in hands of diverse user community in timely fashion**
  - Ability to characterize phenomena and effectively inform appropriate organizations

Example Initiatives for Long Term Vision

- **Sensor techniques**
  - Long-life, tunable Lidar technologies
- **Platform capabilities**
  - Ultralight deployable antennas and telescopes
- **Information systems capabilities**
  - Autonomously reconfigurable communications systems

Implementation

Schedule of Technology Investments

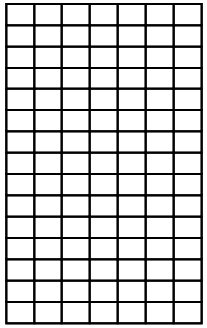


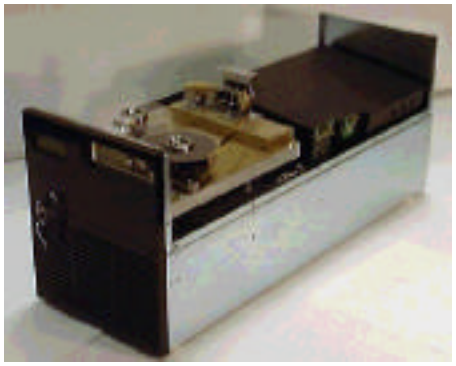
Implementation

- **Instrument and Core Technology Developments**
- **New Millennium Space Flight Validation**
- **High Performance Computing and Communications**

ESTO Technology Investments

Instrument Incubator Program Technology Investments:



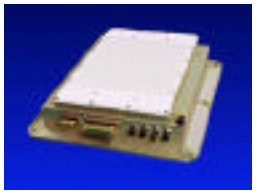


LOTS Optical Tape Drive Prototype

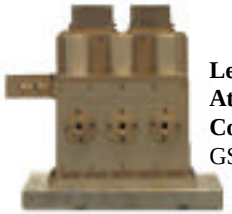
New Millennium Earth Observer 1

Validation of 9 Breakthrough Technologies

- **Advanced Land Imager: reduce costs for future missions**
- **Hyperion: enables new earth science capabilities**



X-Band Phased Array Antenna:
Boeing, GSFC & Lewis Research Center



Leisa Atmospheric Corrector:
GSFC

Advanced Land Imager:
MIT Lincoln Lab, GSFC, Raytheon / Santa Barbara Remote Sensing, & Sensor Systems Group

Carbon-Carbon Radiator:
Air Force Research Lab, Amoco Polymers, BF Goodrich, GSFC, Langley Research Center, Lockheed Martin, Naval Surface Warfare Center, & TRW

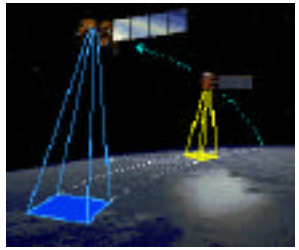
Spacecraft:
GSFC, Litton, SWALES

Hyperion:
TRW, JPL, GSFC

Wideband Advanced Recorder Processor:
GSFC, Litton, MIT Lincoln Lab, Swales, & TRW

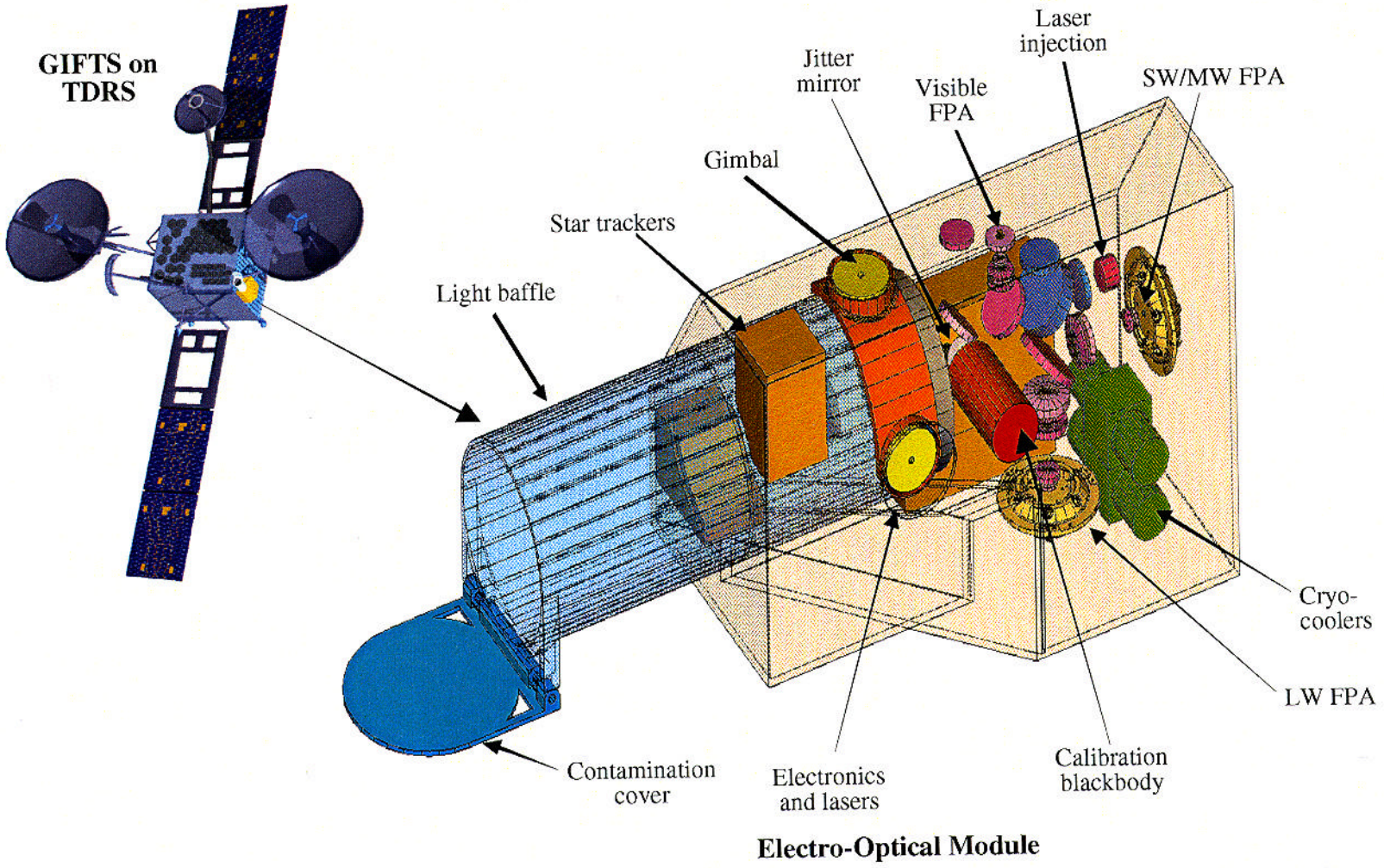
Lightweight Flexible Solar Array:
GSFC, Air Force Research Lab, Lockheed Martin, & Phillips Lab

Pulsed Plasma Thruster:
GSFC, Lewis Research Center & PRIMEX

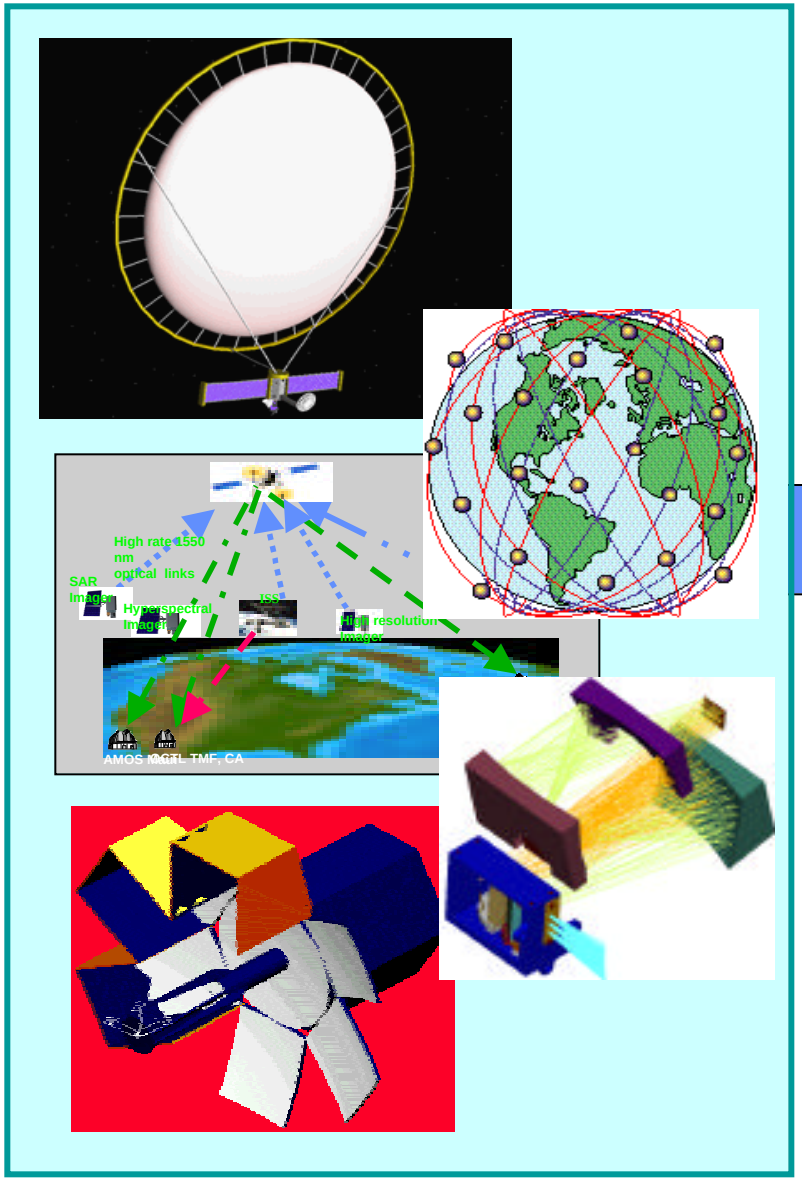


Enhanced Formation Flying
GSFC, JPL

GIFTS Electro-Optical Module



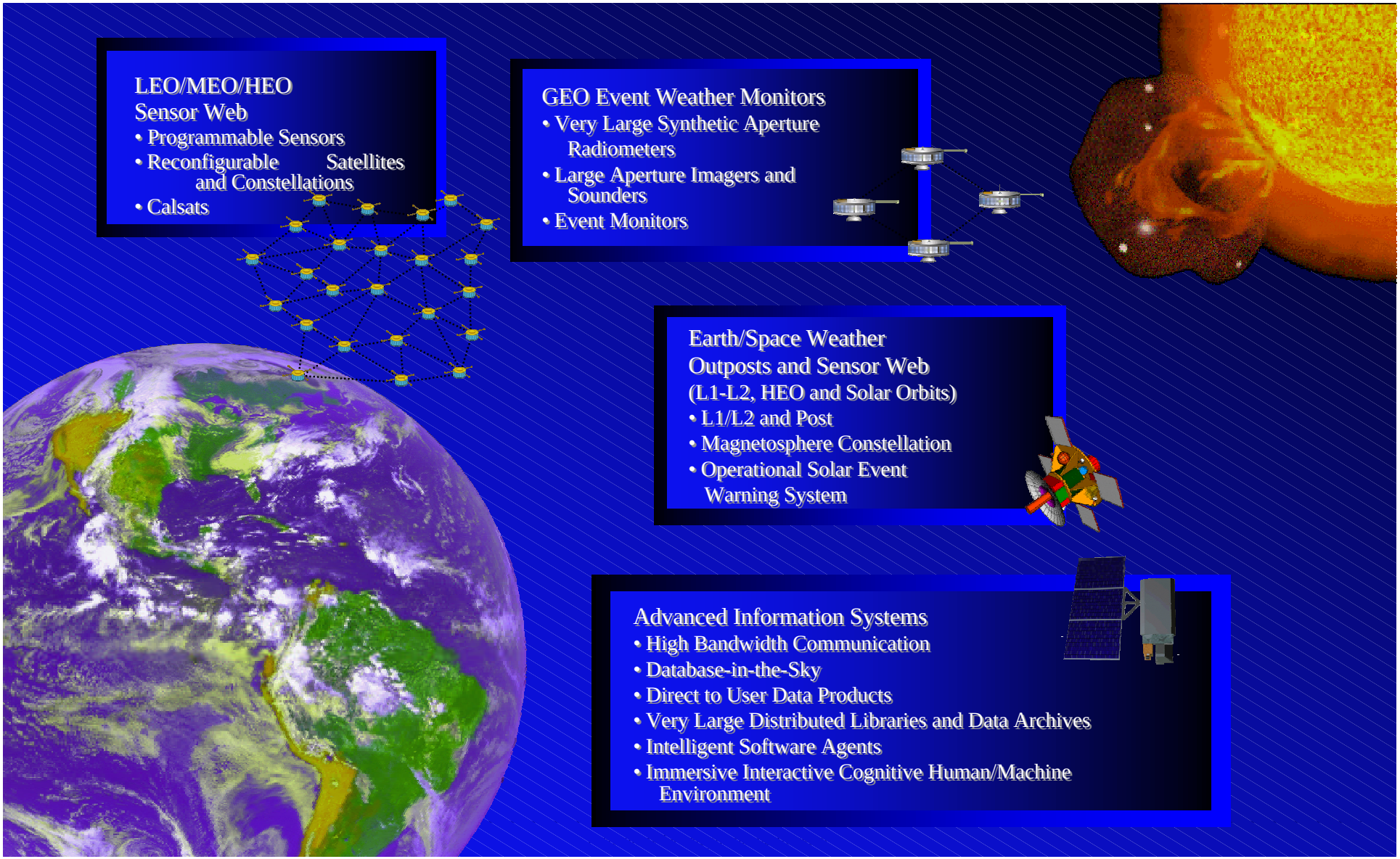
Preliminary Technology Theme Examples to Support Innovative Earth Science Measurements



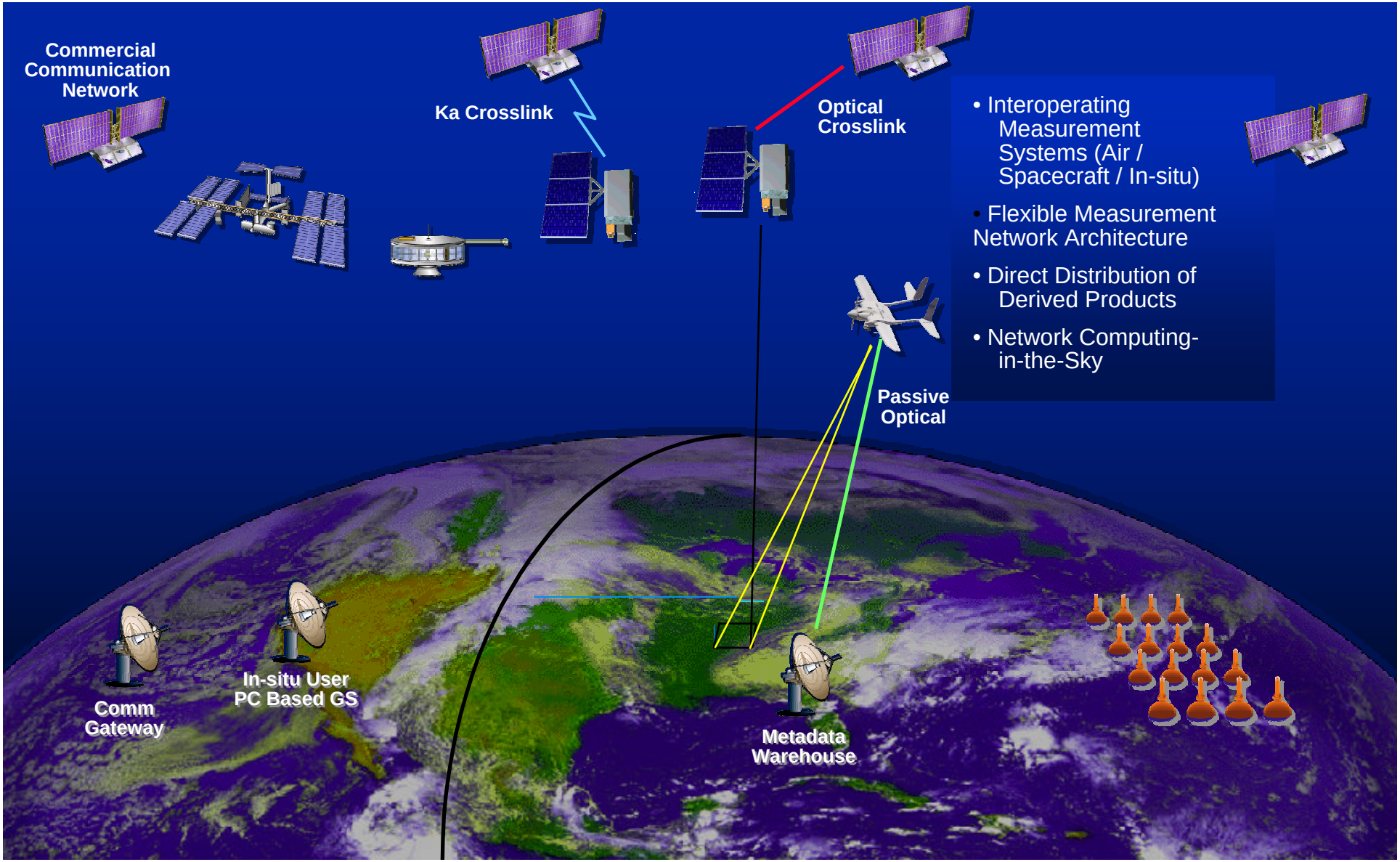
- Large Aperture Lightweight Inflatable/Deployable/Optics/Antennas
  - Radiometers - Radars
  - Lidars - Imagers
- Ultra-high Rate Communications/Onboard Processing
  - High spatial/spectral resolution imaging
- Intelligent Distributed Spacecraft Infrastructure
  - Integrated network observatory
  - Coordinated observations at multiple location/vantage points.

Earth Science Enterprise
National Aeronautics and Space Administration

Distributed Sensing Systems



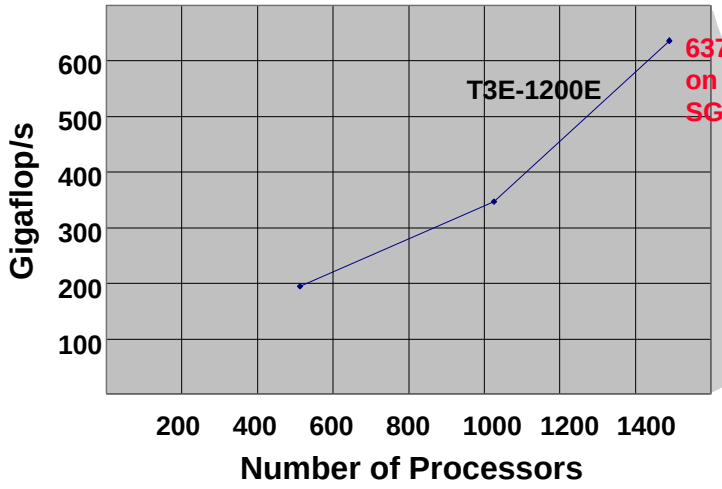
Earth Science Enterprise
National Aeronautics and Space Administration



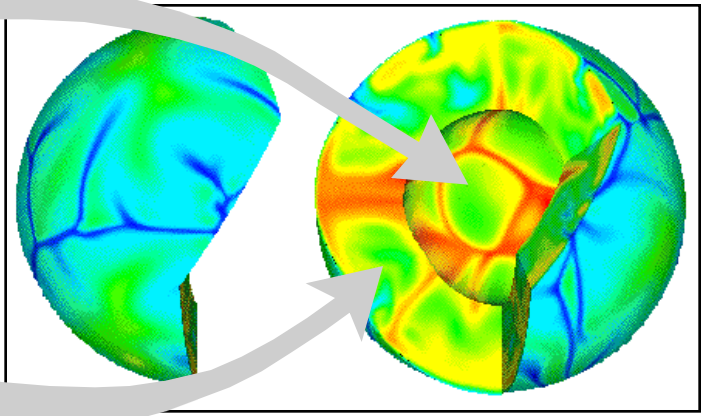
Three-Dimensional Spherical Simulations of Earth's Core and Mantle Dynamics

Peter Olson, Johns Hopkins University, Principal Investigator
http://curie.eps.jhu.edu/nasa3/start.html

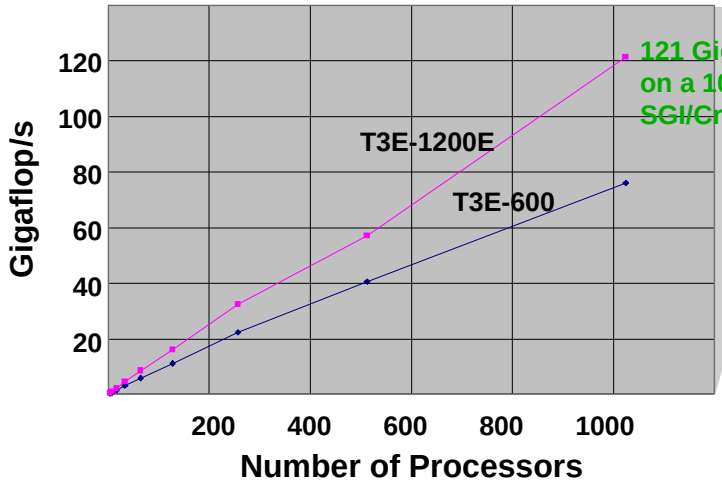
DYNAMO Performance



DYNAMO is a 3-D code for studying the Earth's magnetic dynamo which arises from the turbulent convective processes in the Earth's core. This code solves the full anelastic magnetohydrodynamic (MHD) equations in a spherical geometry using pseudospectral (spherical harmonic expansion) methods.



TERRA Performance



TERRA is a 3-D spherical finite element mantle dynamics code which treats the silicate material that comprises the Earth's mantle as a (non-linear) viscous fluid and solves the Navier-Stokes equations in 3-D spherical geometry for the motions that arise due to the temperature and density variations.

J.Fischer 990113

Program Oversight/Performance Metrics

Technology Program Oversight

- **ESSAAC Technology Subcommittee**
  - …and Full Committee
- **Technology and Commercialization Advisory Committee (TCAC)**
- **Technology Leadership Council (TLC)**
  - Agency -level Sam Venneri
- **OES Strategic Management Reviews**
  - Technology Strategy Team (TST)
- **HQ and Center PMC Reviews**
- **National Academy reviews**
  - Space Studies Board

Metrics

OBJECTIVES

- **Ensure that Enterprise technology programs consider near, mid, and far-term horizons**
- **Maintain a traceable link between science and applications objectives and technology investment**
- **Ensure overall program cost-effectiveness through technology advances and application**
- **Ensure that the Enterprise technology programs support a 3-year acquisition timeline for flight and ground systems**
- **Leverage Enterprise technology investments through cross-Enterprise program synergy and external partnerships**
- **Focus Enterprise resources on critical, high-payoff ESE technology needs through an integrated technology planning process**

OVERALL: Achieve success in timely development and infusion of technologies

Next Steps/Challenges and Opportunities

Earth Science Enterprise
National Aeronautics and Space Administration

Next Steps in Technology Planning

- **Support near-term measurement formulation efforts**
- **Conduct mid-term Measurement Concept assessments (those having late ORDs in next decade)**
- **Identify far-term Vision Technology Needs and Timeline of Initiatives**
- **Support development of an ESE Integrated Information System architecture and performance objectives**

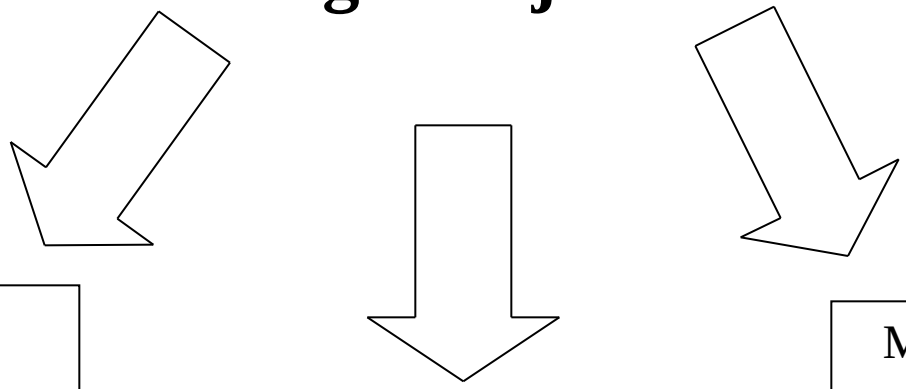
Earth Science Enterprise
National Aeronautics and Space Administration

Challenges and (Opportunities)

- **Implementing (Participating) in the evolving Science-Technology-Mission (or System) paradigm**
- **Seeking early engagement in concept definition and identification of key technologies, while...**
- **Implementing (Participating in) a productive competitive process throughout the Agency including PI Mode, and…**
- **Supporting the various solicitation processes**
- **Correctly assessing technology readiness (especially software related) throughout the development cycle**
- **Ensuring a productive link with Cross-Enterprise technology programs**
- **Building productive external partnerships and joint ventures**

BACKUP

ESE Technology Program Strategic Objectives



Extend Earth Science Measurement Capability and Improve Cost Effectiveness

- Develop new measurement concepts
- Reduce life cycle costs and development times

Maximize Accessibility to and Use of ESE Science Products

- Base on emerging new generation commercial sector concepts
- Improve interoperability, performance, and portability of science software

Meet Agency Policy Requirements and Mandates for Technology

- Infuse NASA Technology into the U.S. Economy
- Promote and Maintain U.S. World Leadership in Remote Sensing
- Maintain critical NASA core competencies

Technology Development Functional Responsibilities

Strategic Planning (HQ with ESTO/TST support)

- Technology Program PCAs/Approve Program Plans
- Technology Capability/Needs Assessments
- Integrated Technology Development/Investment Plan
- Annual Technology Infusion Plan
- Oversee and Evaluate technology program implementation

Program Implementation (Managed as Center Programs)

- Guided by Specific Program Plans
- Earth Science Technology Program (ESTP at ESTO)
- New Millennium Program
- High Performance Computing and Communications (HPCC)
- Solicitations by HQ, supported by Program Offices

Technology Program Management

Strategic Management

- Overall Strategic guidance
- Office Work Instructions (OWIs)
- Formulation Authorization
- Technology Program PCAs
- Approval of key planning documents

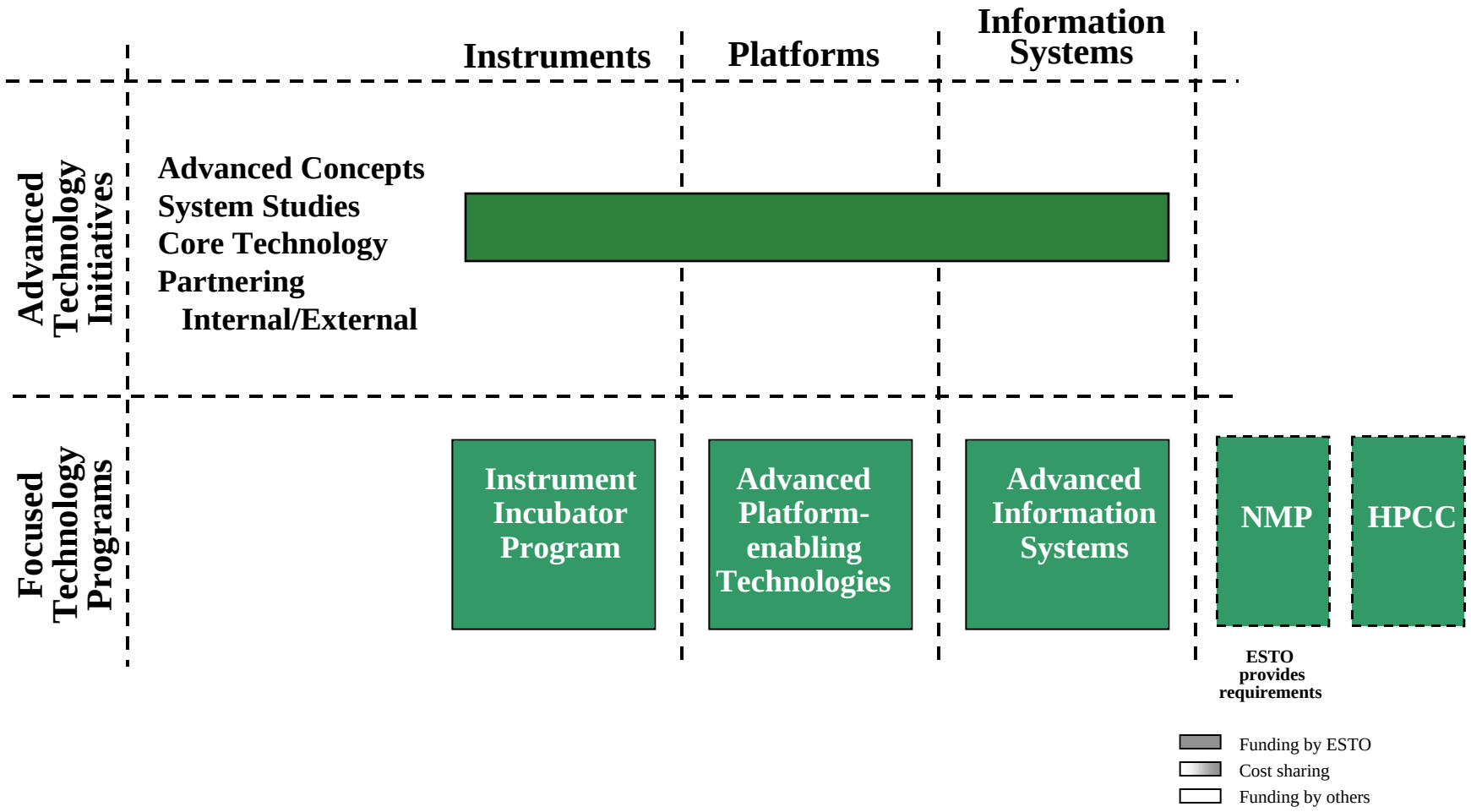
Program Coordination and Advocacy

- Technology Strategy Team (TST)
  - Lead Technologist-Chair
  - ESTO Manager-Executive Secretary
- ESSAAC Technology Subcommittee (Advisory)
- Technology Leadership Council (TLC)--S. Venneri activity
  - Provides Agency level policies, strategic thrusts, and integrated view of programs

Program/Project Implementation

- Earth Science Technology Office (located at GSFC)
  - Overall requirements integration and support to Strategic Planning
  - Responsible for Broad -based Program Plan
- New Millennium Program
  - JPL and GSFC
- HPCC/Earth and Space Science
  - GSFC/JPL/AMES

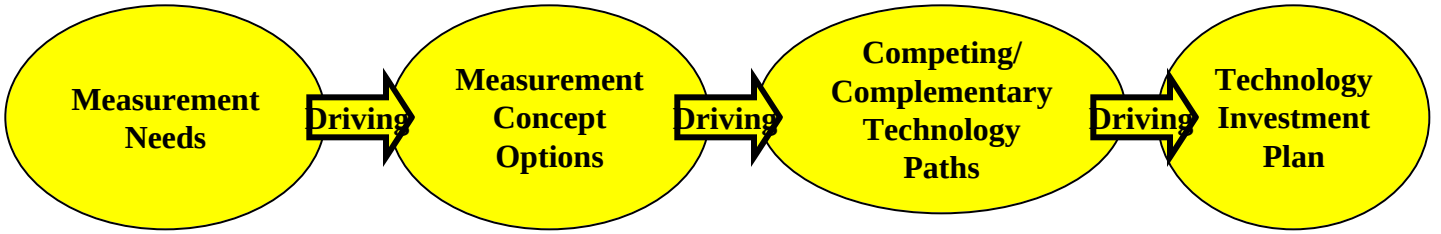
Technology Program Implementation



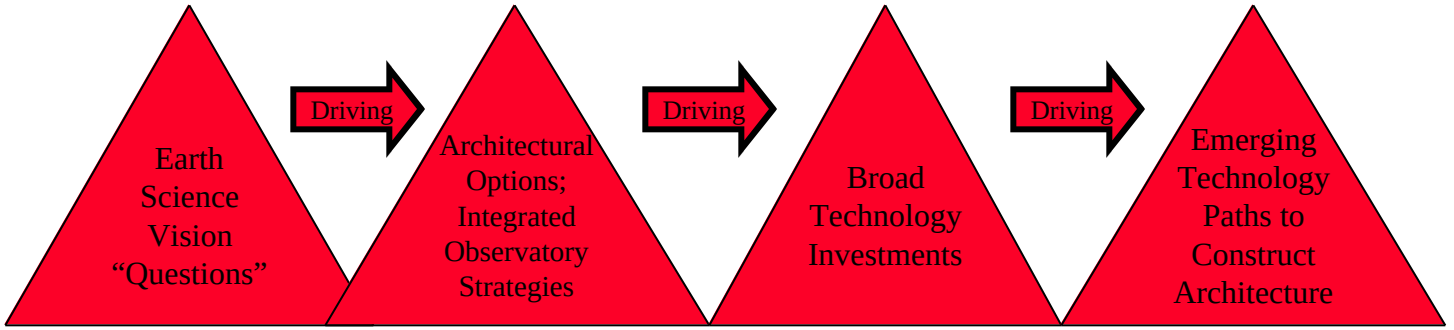
Technology Planning Horizons

NEAR TERM

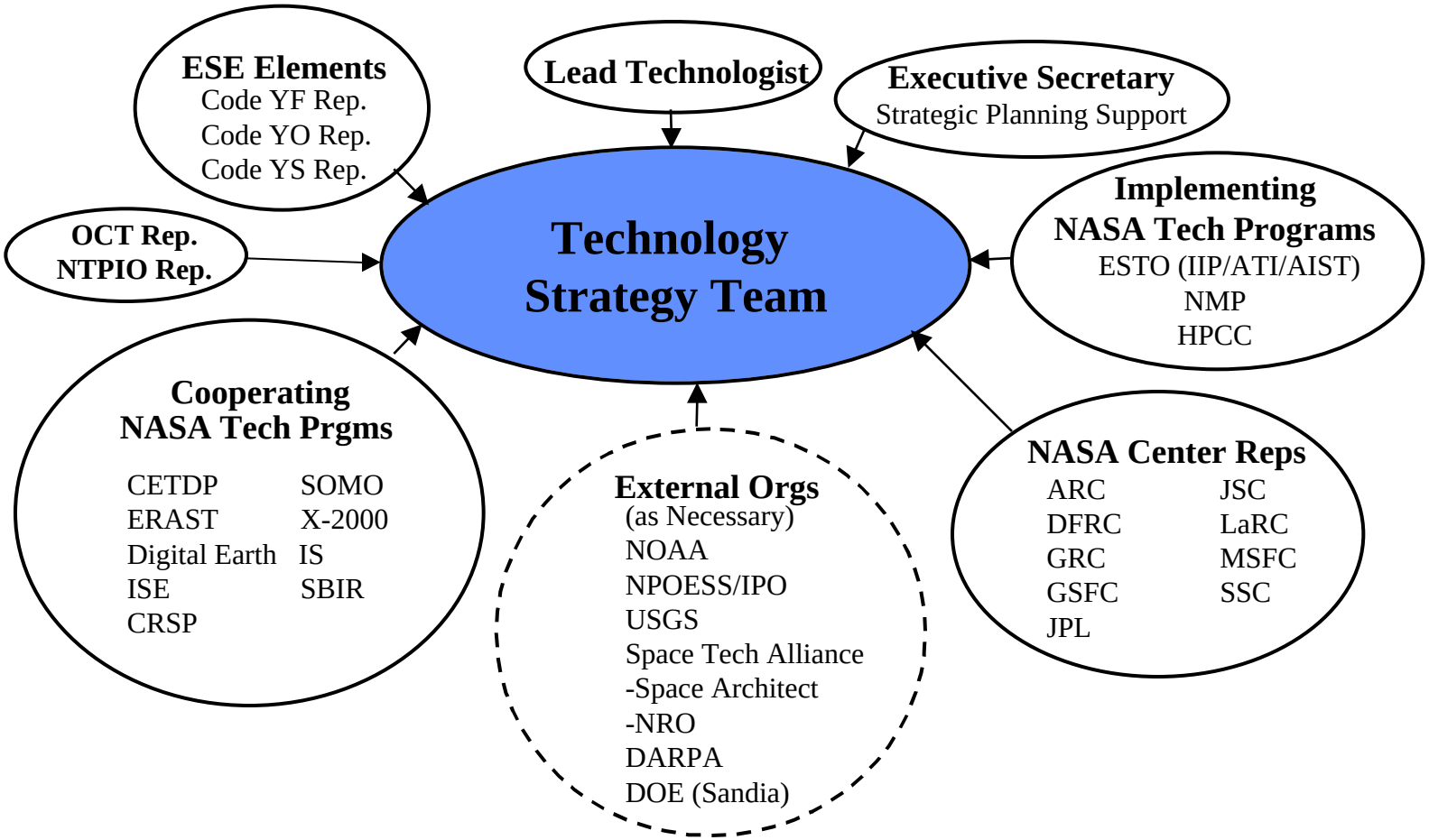
MID TERM



FAR TERM



Technology Strategy Team Participants



OES Near-and Mid-Term Technology Development Thrusts (being updated)

Instrument and Measurement Technologies Development

- **Active Sensor Systems (Lidar and LightSAR)**
- **Passive Miniature Atmospheric sensors and Earth surface imaging sensors**
  - **EO-1 Land Imager Alternatives (hyper- and multi-spectral)**
  - **EOS Follow-on Instrument Development**
- **Airborne and In Situ Sensor Technology (R&A, co-investment with Core Technology)**

Information Systems Technologies

- **Advanced on-orbit data processing/compression techniques**
  - **EO-1 Fiber Optic Databus, Cloud Editing**
  - **EO-1 application of formation flying concepts and data synthesis**
- **Advanced information systems architectures**
  - **EOSDIS Alternate Architecture Studies and testbeds**
  - **EOSDIS Federation Approach --highly distributed, advanced INTERNET interfaces**
- **Supercomputing initiatives in large-scale modeling and image visualization**

Spacecraft Technologies

- **OES Reliance on Industry for Spacecraft and Spacecraft Technology (IDIQ)**
- **Linkage to NASA intragency Developments**
  - **Core Program, SBIR, X-2000 Advanced Miniaturization**

Autonomous Operations

- **End-to-end communications, constellation architectures, intelligent systems**

Web page reference for accomplishments

http://esto.gsfc.nasa.gov/workshops/fy99/fy99.html

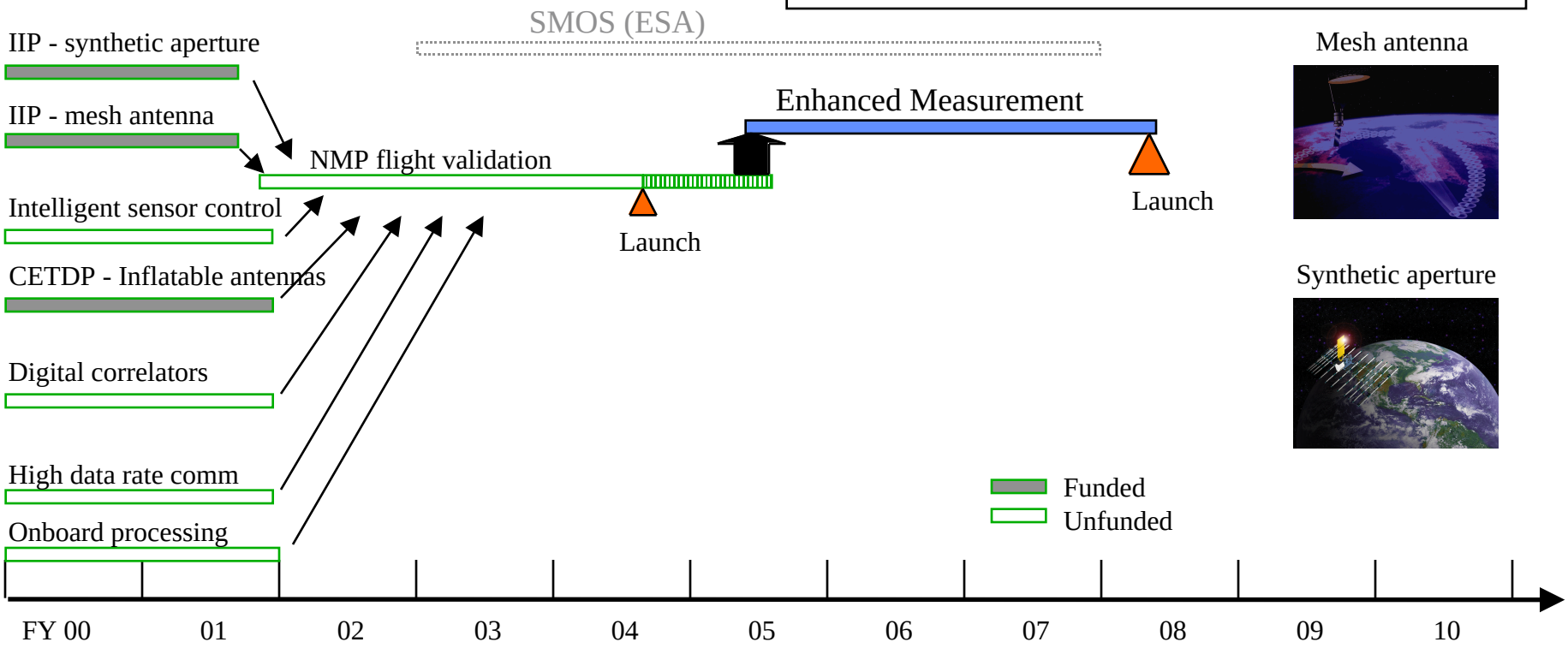
Soil Moisture Measurement--Sample Roadmap

OBJECTIVE: Provides the ability to detect and measure volumetric moisture in the upper 5-10 cm of the soil with spatial resolution 10-30km and 2-3 day revisit time.

TECHNOLOGY CHALLENGE: Current concepts offer two competing instrument technology paths:

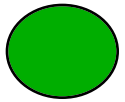
- **Synthetic aperture radiometer with thinned antenna array**
- **Real aperture radiometer with mesh antenna**

Both options enable and require investment to answer technological readiness, risk of deployment, structural stability on orbit, and growth potential questions.



Accomplishments - How Well Have We've Done

Enterprise Metrics



G

(Metric 24) Demonstrate a new capability to double the calibration quality for moderate resolution land imagery

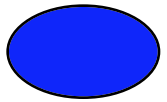
MODIS preflight instrument pre-launch testing and integration on Terra completed. Pre-launch calibration and characterization of MODIS protoflight instrument confirms significant improvements in absolute calibration accuracy of moderate resolution land imagery. The inter-calibration activities carried out by MODIS science teams in cooperation with NIST established an absolute radiometric accuracy of better than 5%, which is consistent with the target.

Should be on target for accomplishing this metric during FY 2000. However, final confirmation of this objective can not be made until post-launch validation activities. Delays in the launch of Terra, due to launch vehicle re-certification, have prevented this from occurring.

Accomplishments - How Well Have We've Done

Enterprise Metrics

(Metric 25) Annual transfer of at least one (1) technology development to a commercial entity or into operational use.



B

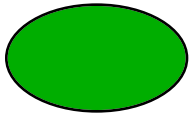
Laser Optical Tape System (LOTS) developed under ESDIS Prototyping is being commercialized by Kodak.

Sensor & Detector funding spawned the pursuit of non-pressurized laser designs by small company (Fibertek) to improve profitability.

Space Act Technology partnership (GSFC/Swales) to transfer SMEX-Lite Spacecraft architecture and related technologies

(Metric 26) Annually advance at least twenty-five (25) percent of funded instrument technology developments by at least one readiness level (TRL) each year.

Based in the FY'99 investments in the Instrument Incubator Program, 7 out of 27 projects or 25% have advanced at least one TRL.



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